Readmission after seizure discharge in a nationally representative sample

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Abstract

Objective

To determine the 30-day readmission rate after seizure-related discharge in a nationally representative sample, as well as patient, clinical, and hospital characteristics associated with readmission.

Methods

Retrospective cohort study of adults discharged alive from a nonelective hospitalization for epilepsy or seizure, sampled from the Healthcare Cost and Utilization Project's 2014 Nationwide Readmissions Database. Descriptive statistics and logistic regression models were built to quantify and characterize nonelective readmission within 30 days.

Results

A total of 139,800 admissions met inclusion criteria, of which 15,094 (10.8%) were readmitted within 30 days. Patient characteristics associated with readmission included comorbid disease burden (Elixhauser score 2: adjusted odds ratio [AOR] [95% confidence interval (CI)] 1.38 [1.21–1.57]; Elixhauser score 3: AOR 1.52 [1.34–1.73]; Elixhauser score >4: AOR 2.28 [2.01–2.58] as compared to 1) and participation in public insurance programs (Medicare: AOR 1.39 [1.26–1.54]; Medicaid: AOR 1.39 [1.26–1.54] as compared to private insurance). Adverse events (AOR 1.17 [1.05–1.30]) and prolonged length of stay, as well as nonroutine discharge (AOR 1.32 [1.23–1.42]), were also associated with increased adjusted odds of readmission. The most common primary reason for readmission was epilepsy or convulsion (17%).

Conclusions

Patients hospitalized with seizure are frequently readmitted. While readmitted patients are more likely to have multiple medical comorbidities, our study demonstrated that inpatient adverse events were also significantly associated with readmission. The most common reason for readmission was seizure or epilepsy. Together, these 2 findings suggest that a proportion of readmissions are related to modifiable care process factors and may therefore be avoidable. Further study into understanding preventable drivers of readmission in this population presents an opportunity to improve patient outcomes and health.

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Glossary

AOR = adjusted odds ratio; CI = confidence interval; ICD-9 = International Classification of Diseases–9; NRD = Nationwide Readmissions Database; OR = odds ratio.

As health care costs continue to rise, increasing attention has focused on the question of how to provide high value patient care.¹ Current health care legislation contains payment incentives aimed at improving quality of care and lowering costs, and readmissions have emerged as a cornerstone indicator of quality and value in inpatient care.² Hospital readmissions in 2011 were estimated to have cost \$41.3 billion in the United States.³ In order to achieve mandates for reduced readmissions, it is necessary to understand the drivers of readmission.

Previous studies have examined the frequency of readmission in a subset of the population with epilepsy (members of a particular health plan) or in specific patient populations admitted with seizure such as postsurgical patients, and found readmission rates from less than 5% to 29%.^{4–8} This variability likely reflects the effects of differences in patient and hospital characteristics and limits our ability to rely on the current literature for benchmark readmission data. Therefore, on a national level, little is known about the risk factors for readmission of seizure patients or the burden of readmission in this population. We attempted to address this knowledge gap by examining readmissions after admission for seizure in a nationally representative sample. The primary objective of this study was to determine the national 30-day nonelective readmission rate in patients emergently hospitalized for seizure. Secondary objectives were to identify patient and hospitalization characteristics associated with nonelective readmission at 30 and 90 days.

Methods

Data

We utilized data from the US Healthcare Cost and Utilization Project's 2014 Nationwide Readmissions Database (NRD), the largest all-payer inpatient health care national readmissions database, which is made available by the Agency for Healthcare Research and Quality. This database contains de-identified information regarding patient demographics, measures of comorbidity, diagnoses, procedures, admission and disposition details, payer information, and hospital characteristics. Our study examined seizure and epilepsy admissions from approximately 35 million distinct hospitalizations in 2014.

Study design and population

We performed a retrospective cohort study of emergently hospitalized adults with a primary discharge diagnosis of seizure or epilepsy, as defined by the ICD-9 diagnosis codes for convulsion (ICD-9 780.3) or epilepsy (ICD-9 345.x).^{9,10} If an

individual had more than one potential qualifying hospitalization in 2014 (any hospitalization with a primary discharge diagnosis of seizure or epilepsy), we randomly chose one of these hospitalizations to serve as the index encounter. Admissions were excluded if the patient was younger than 18 years or died during the index hospitalization, if the hospitalization was designed as elective, if the patient left against medical advice, or if the hospitalization occurred less than 30 days (or 90 days) prior to the end of the year (due to insufficient follow-up).

Patient and clinical characteristics

We extracted data on patient characteristics including age, sex, primary payment source (Medicare, Medicaid, private insurance, uninsured/self-pay, no charge, other), and median household income (categorized in the NRD as quartiles of the median income in the patients' postal code). Age was also categorized as 18–39 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years, or 80+ years. The NRD does not include data on race/ethnicity. NRD software allows researchers to identify 29 preexisting chronic medical conditions and to calculate an Elixhauser comorbidity score. The Elixhauser comorbidity score was categorized as 0–1, 2, 3, and 4+ comorbid conditions. Hospital characteristics available in the NRD include teaching status, hospital bed size, and hospital control (government, nonprofit, for-profit). The NRD does not allow researchers to perform hierarchical analyses at the hospital level, which is necessary to examine the relationship between provider capacity or volume and outcomes.

Outcomes

The primary outcome was nonelective readmission within 30 days. We considered only the first nonelective readmission within the observation window. A secondary outcome was nonelective readmission within 90 days. If an individual had more than one nonelective readmission during the 30- or 90-day window, we considered only the first readmission in our analysis. We also examined readmission rates associated with complications of seizure as defined by ICD codes: status epilepticus, altered mental status/delirium, and mechanical ventilation/endotracheal intubation (appendix 1). Finally, adverse events were identified using ICD-9 codes E8700–E8799 (for adverse effects of medical care) and E9300–E9499 (for adverse effects of medical drugs).

In secondary analyses, we examined readmission rates in subgroups of patients with the following additional diagnoses present at the index admission: brain tumor, intracerebral hemorrhage, subarachnoid hemorrhage, traumatic brain injury, intoxication, and CNS infection (see appendix 1 for related ICD-9 codes, as well as references for prior validation studies).

Table 1 Patient and hospital characteristics of adults hospitalized for epilepsy or convulsions, Nationwide Readmissions Database, 2014

Characteristics	30-day readmission status, n (%)		<i>p</i> Value, χ^2 test
	Readmitted (n = 15,094)	Not readmitted (n = 124,706)	
Age group, y			<0.0001
18–24	742 (4.9)	9,743 (7.8)	
25–34	1,514 (10)	15,263 (12.2)	
35–44	1,709 (11.3)	15,777 (12.7)	
45–54	2,622 (17.4)	21,362 (17.1)	
55–64	3,103 (20.6)	23,297 (18.7)	
65–74	2,448 (16.2)	17,899 (14.4)	
75–84	1,863 (12.3)	13,345 (10.7)	
85+	1,092 (7.2)	8,021 (6.4)	
Sex			0.0175
Male	7,326 (48.5)	62,604 (50.2)	
Female	7,768 (51.5)	62,102 (49.8)	
Primary payer type			<0.0001
Medicare	8,369 (55.5)	57,667 (46.3)	
Medicaid	3,569 (23.7)	28,197 (22.6)	
Private insurance	2,011 (13.3)	24,566 (19.7)	
Self-pay/no charge/other	1,131 (7.5)	14,143 (11.4)	
Zip code quartile			0.0973
\$1–\$37,999	5,277 (35.5)	41,615 (33.9)	
\$38,000–\$47,999	3,878 (26.1)	32,540 (26.5)	
\$48,000–\$63,999	2,971 (20)	25,790 (21)	
\$64,000+	2,723 (18.3)	22,995 (18.7)	
Hospital control type			0.9832
Government, nonfederal	1,868 (12.4)	15,516 (12.4)	
Private, nonprofit	10,693 (70.8)	88,360 (70.9)	
Private, for-profit	2,533 (16.8)	20,830 (16.7)	
Hospital bed size			0.6745
Small	2,129 (14.1)	17,861 (14.3)	
Medium	4,274 (28.3)	34,619 (27.8)	
Large	8,691 (57.6)	72,226 (57.9)	
Hospital teaching status and location			0.1957
Metropolitan nonteaching	4,151 (27.5)	34,427 (27.6)	
Metropolitan teaching	9,953 (65.9)	81,160 (65.1)	
Nonmetropolitan	989 (6.6)	9,119 (7.3)	
Elixhauser score			<0.0001
0–1	836 (5.5)	14,406 (11.6)	

Continued

Table 1 Patient and hospital characteristics of adults hospitalized for epilepsy or convulsions, Nationwide Readmissions Database, 2014 (continued)

Characteristics	30-day readmission status, n (%)		p Value, χ^2 test
	Readmitted (n = 15,094)	Not readmitted (n = 124,706)	
2	2,057 (13.6)	24,509 (19.7)	
3	2,812 (18.6)	28,607 (22.9)	
4+	9,389 (62.2)	57,184 (45.9)	
AIDS	111 (0.7)	598 (0.5)	0.0127
Alcohol abuse	2,156 (14.3)	15,012 (12)	<0.0001
Deficiency anemias	3,270 (21.7)	16,257 (13)	<0.0001
Rheumatoid arthritis/collagen vascular diseases	497 (3.3)	2,991 (2.4)	0.0004
Chronic blood loss anemia	41 (0.3)	330 (0.3)	0.9085
Congestive heart failure	1,551 (10.3)	7,190 (5.8)	<0.0001
Chronic pulmonary disease	3,103 (20.6)	19,129 (15.3)	<0.0001
Coagulopathy	978 (6.5)	5,487 (4.4)	<0.0001
Depression	2,706 (17.9)	20,562 (16.5)	0.0065
Diabetes, uncomplicated	3,213 (21.3)	20,494 (16.4)	<0.0001
Diabetes, complicated	1,003 (6.6)	4,433 (3.6)	<0.0001
Drug abuse	1,696 (11.2)	14,790 (11.9)	0.1589
Hypertension	8,823 (58.5)	62,040 (49.7)	<0.0001
Hypothyroidism	1,983 (13.1)	14,017 (11.2)	0.0001
Liver disease	716 (4.7)	3,655 (2.9)	<0.0001
Lymphoma	140 (0.9)	624 (0.5)	0.0009
Fluid and electrolyte disorders	5,598 (37.1)	38,886 (31.2)	<0.0001
Metastatic cancer	548 (3.6)	2,196 (1.8)	<0.0001
Other neurologic disorders	39 (0.3)	218 (0.2)	0.2205
Obesity	1,299 (8.6)	9,541 (7.7)	0.0136
Paralysis	1,912 (12.7)	13,841 (11.1)	0.0006
Peripheral vascular disorders	747 (4.9)	4,038 (3.2)	<0.0001
Psychoses	2,508 (16.6)	15,415 (12.4)	<0.0001
Pulmonary circulation disorders	354 (2.3)	1,474 (1.2)	<0.0001
Renal failure	2,553 (16.9)	10,406 (8.3)	<0.0001
Solid tumor without metastasis	446 (3)	2,739 (2.2)	0.0033
Peptic ulcer disease excluding bleeding	^a	26 (0)	0.2749
Valvular disease	649 (4.3)	4,225 (3.4)	0.0006
Weight loss	809 (5.4)	4,224 (3.4)	<0.0001
Length of stay, d			<0.0001
1–2	5,586 (37)	63,384 (50.8)	
3–6	6,383 (42.3)	46,727 (37.5)	
7 or more	3,125 (20.7)	14,595 (11.7)	

Continued

Table 1 Patient and hospital characteristics of adults hospitalized for epilepsy or convulsions, Nationwide Readmissions Database, 2014 (continued)

Characteristics	30-day readmission status, n (%)		p Value, χ^2 test
	Readmitted (n = 15,094)	Not readmitted (n = 124,706)	
Disposition			<0.0001
Home/routine	8,253 (54.7)	83,795 (67.2)	
Inpatient post acute care	3,945 (26.1)	22,375 (17.9)	
Home with health care	2,264 (15)	13,799 (11.1)	
Other	632 (4.2)	4,738 (3.8)	
Adverse events: any	1,527 (10.1)	9,069 (7.3)	<0.0001
Adverse events: medical care	353 (2.3)	1,572 (1.3)	<0.0001
Adverse events: medications	1,216 (8.1)	7,690 (6.2)	<0.0001

^a Data (n ≤ 10) not reported due to HCUP privacy guidelines.

Statistical analysis

Demographic characteristics were compared using χ^2 tests for categorical variables. To examine patient, hospital, and clinical characteristics associated with readmission, we built multivariable logistic regression models to estimate the odds of readmission for each characteristic. Model variables were initially selected a priori based on clinical knowledge and review of existing literature and variable availability in NRD data. All estimates were generated using survey-weighted methods to account for the complex survey design of the NRD and generate national estimates for all variables. In particular, we used the full cohort to maintain all strata and yield proper variance estimates as intended by HCUP. The statistical analyses for our study were performed using SAS software, version 9.4 (SAS Institute, Inc., Cary, NC).

Standard protocol approvals, registrations, and patient consents

This study was approved by the University of Pennsylvania's Institutional Review Board.

Data availability statement

The US Healthcare Cost and Utilization Project's 2014 Nationwide Readmissions Database is a publicly available dataset.

Results

Demographics

We identified a total of 139,800 hospitalizations that met all inclusion criteria for 30-day readmission. Of these, 15,094 patients (10.8%) were readmitted within 30 days. Table 1 displays patient, clinical, and hospitalization characteristics of the study sample, stratified by readmission status. A total of 79.2% of readmitted patients had public insurance, either through the Medicare or Medicaid programs, compared to 68.9% of non-readmitted patients. Male and female patients were distributed similarly by readmission status. Comorbid disease burden was

greater among readmitted patients—62.2% of persons who were readmitted had 4 or more chronic medical conditions, compared to 45.9% of persons not readmitted. Of the 29 chronic conditions that are able to be identified in the NRD, all but 2 (drug abuse, chronic blood loss anemia) were more frequent among readmitted patients. Readmitted patients more frequently utilized postacute care (either home health care or discharge to a facility), 41.1% vs 29.0% among nonreadmitted persons, and more frequently had an index hospitalization lasting a week or more. Finally, an adverse event was recorded more often during the index admission of readmitted patients (10.1% vs 7.3% in nonreadmitted). The distribution of median zip code income and hospital characteristic categories did not significantly vary by readmission status. The most common reason for readmission was epilepsy or convulsion, followed by sepsis (17% and 7% of readmissions, respectively).

Factors associated with 30-day readmission

Multivariate logistic regression models that included patient, clinical, and index hospitalization characteristics produced adjusted odds ratios (AORs) that demonstrated that several study variables were associated with readmission. As shown in table 2, public insurance program participation (Medicare AOR 1.48 [95% confidence interval (CI) 1.34–1.62] or Medicaid AOR 1.39 [95% CI 1.26–1.54] as compared to private insurance), discharge to an inpatient care facility (AOR 1.32, 95% CI 1.23–1.42 as compared to home), a higher Elixhauser comorbidity score (4+ conditions AOR 2.28, 95% CI 2.01–2.58 compared to ≤ 1 condition), and a longer index admission stay (7+ days AOR 1.78, 95% CI 1.63–1.95) were associated with 30-day readmission. Among patient characteristics, age greater than 85 years was associated with lower odds of readmission (AOR 0.79, 95% CI 0.65–0.95) after adjusting for covariates. Documented adverse events during the index admission (AOR 1.17 95% CI 1.06–1.30) were also associated with increased adjusted odds of readmission. When these events were subcategorized,

Table 2 Factors associated with 30-day readmission

Characteristic	Readmission rate, 30 days (row percent)	Adjusted odds ratio of 30-day readmission (95% CI)	p Value
Age, y			
18–24	742 (7.1)	Reference	
25–34	1,514 (9)	1.12 (0.95–1.33)	0.1753
35–44	1,709 (9.8)	1.12 (0.95–1.31)	0.1776
45–54	2,622 (10.9)	1.09 (0.93–1.27)	0.3138
55–64	3,103 (11.8)	1.04 (0.88–1.22)	0.6404
65–74	2,448 (12)	0.89 (0.75–1.05)	0.1623
75–84	1,863 (12.2)	0.84 (0.7–1.01)	0.0601
85+	1,092 (12)	0.79 (0.65–0.95)	0.0105
Sex			
Male	7,326 (10.5)	Reference	
Female	7,768 (11.1)	1.03 (0.98–1.09)	0.254
Primary insurance			
Medicare	8,369 (12.7)	1.48 (1.34–1.62)	<0.0001
Medicaid	3,569 (11.2)	1.39 (1.26–1.54)	<0.0001
Private	2,011 (7.6)	Reference	
Self-pay/no charge/other	1,131 (7.4)	0.96 (0.85–1.09)	0.5628
Zip code quartile			
\$1–\$37,999	5,277 (11.3)	1.02 (0.94–1.11)	0.5980
\$38,000–\$47,999	3,878 (10.6)	1 (0.92–1.09)	0.9540
\$48,000–\$63,999	2,971 (10.3)	0.97 (0.88–1.06)	0.4400
\$64,000+	2,723 (10.6)	Reference	
Disposition			
Home/routine	8,253 (9)	Reference	
Inpatient post acute care	3,945 (15)	1.32 (1.23–1.42)	<0.0001
Home with home health care	2,264 (14.1)	1.28 (1.17–1.4)	<0.0001
Other	632 (11.8)	1.48 (1.29–1.71)	<0.0001
Elixhauser			
0–1	836 (5.5)	Reference	
2	2,057 (7.7)	1.38 (1.21–1.57)	<0.0001
3	2,812 (8.9)	1.52 (1.34–1.73)	<0.0001
4+	9,389 (14.1)	2.28 (2.01–2.58)	<0.0001
Length of index stay, d			
1–2	5,586 (8.1)	Reference	
3–6	6,383 (12)	1.33 (1.24–1.42)	<0.0001
7 or more	3,125 (17.6)	1.78 (1.63–1.95)	<0.0001

Continued

Table 2 Factors associated with 30-day readmission (*continued*)

Characteristic	Readmission rate, 30 days (row percent)	Adjusted odds ratio of 30-day readmission (95% CI)	p Value
Teaching status			
Metropolitan nonteaching	4,151 (10.8)	0.98 (0.92–1.05)	0.5806
Metropolitan teaching	9,953 (10.9)	Reference	
Nonmetropolitan	989 (9.8)	0.87 (0.76–1.01)	0.0620

Abbreviation: CI = confidence interval.

medication adverse events were no longer statistically significant (odds ratio [OR] 1.12, 95% CI 0.99–1.26), but medical or surgical events (OR 1.34, 95% CI 1.10–1.62) remained associated with readmission.

Association with specific comorbidities and complications

Our secondary analysis focused on risk factors for secondary epilepsy and diagnoses suggestive of a complicated index course or complicated epilepsy. Readmission was positively

associated with a concomitant diagnosis of brain tumor (AOR 1.43, 95% CI 1.21–1.68), CNS infection (AOR 1.72 95% CI 1.23–2.39), and alcohol use (AOR 1.21, 95% CI 1.09–1.34), but not with mechanical ventilation, delirium, traumatic brain injury, subarachnoid hemorrhage, ischemic stroke, intracerebral hemorrhage, other drug intoxicants, aspiration pneumonia, shoulder dislocation, or status epilepticus (table 3). The findings described above were similar when the analysis was repeated using 90-day readmissions, although the 90-day readmission rate was 21.4% (tables 4–6).

Table 3 Comorbidities and complications associated with 30-day readmission

	Readmission rate (%)	Adjusted odds ratio of 30-day readmission (95% CI)	p Value
Conditions			
Brain tumor	600 (16.3)	1.43 (1.21–1.68)	<0.0001
Ischemic stroke	757 (11.5)	0.86 (0.76–0.98)	0.0191
Intracerebral hemorrhage	63 (18.6)	1.48 (0.96–2.27)	0.0774
Subarachnoid hemorrhage	^a	0.69 (0.25–1.88)	0.4661
Traumatic brain injury	216 (9.8)	0.91 (0.72–1.14)	0.4009
CNS infection	156 (21.7)	1.72 (1.23–2.39)	0.0014
Alcohol ingestion/dependence/intoxication/withdrawal	1,337 (14)	1.21 (1.09–1.34)	0.0005
THC	0 (0.0)	NA	
Antidepressant nondependent abuse, poisoning by AEDs	13 (10.7)	1.03 (0.38–2.8)	0.9527
Sedative, hypnotics, anxiolytics intoxication/dependence	^a	1.92 (0.62–5.99)	0.2600
Cocaine, amphetamines, hallucinogens intoxication/dependence	0 (0)	NA	
Associated complications			
Delirium/altered mental status	3,710 (12.7)	1.04 (0.97–1.11)	0.2816
Status epilepticus	1,654 (12.3)	0.95 (0.86–1.05)	0.2814
Mechanical ventilation/endotracheal intubation	1,345 (12.8)	0.86 (0.77–0.96)	0.0082
Shoulder dislocation	11 (11.3)	1.54 (0.58–4.07)	0.3816
Aspiration pneumonia	684 (14.4)	0.98 (0.85–1.14)	0.8108

Abbreviations: AED = antiepileptic drug; CI = confidence interval; THC = tetrahydrocannabinol.

^a Data (n ≤ 10) not reported due to HCUP privacy guidelines.

Table 4 Patient and hospital characteristics for 90-day readmission analyses

Characteristics	Readmitted (n = 24,725)	Not readmitted (n = 90,946)	p Value
Age group, y			<0.0001
18–24	1,301 (5.3)	7,317 (8)	
25–34	2,404 (9.7)	11,486 (12.6)	
35–44	2,788 (11.3)	11,821 (13)	
45–54	4,382 (17.7)	15,766 (17.3)	
55–64	4,968 (20.1)	16,695 (18.4)	
65–74	4,050 (16.4)	12,716 (14)	
75–84	3,004 (12.2)	9,418 (10.4)	
85+	1,827 (7.4)	5,727 (6.3)	
Sex			0.1778
Male	12,156 (49.2)	45,440 (50)	
Female	12,569 (50.8)	45,506 (50)	
Primary payer type			<0.0001
Medicare	13,639 (55.2)	40,879 (45)	
Medicaid	5,969 (24.2)	20,438 (22.5)	
Private insurance	3,144 (12.7)	18,627 (20.5)	
Self-pay/no charge/other	1,963 (7.9)	10,906 (12)	
Zip code quartile			0.0005
\$1– \$37,999	8,748 (35.9)	29,953 (33.4)	
\$38,000–\$47,999	6,343 (26.1)	23,955 (26.7)	
\$48,000–\$63,999	4,819 (19.8)	18,848 (21)	
\$64,000+	4,438 (18.2)	16,909 (18.9)	
Hospital control type			0.5660
Government, nonfederal	3,067 (12.4)	11,207 (12.3)	
Private, nonprofit	17,429 (70.5)	64,648 (71.1)	
Private, for profit	4,229 (17.1)	15,091 (16.6)	
Hospital bed size			0.8821
Small	3,579 (14.5)	12,976 (14.3)	
Medium	6,923 (28)	25,424 (28)	
Large	14,224 (57.5)	52,546 (57.8)	
Hospital teaching location			0.0013
Metropolitan nonteaching	6,846 (27.7)	25,110 (27.6)	
Metropolitan teaching	16,371 (66.2)	59,130 (65)	
Nonmetropolitan	1,508 (6.1)	6,707 (7.4)	
Elixhauser score			<0.0001
0–1	1,447 (5.9)	11,248 (12.4)	
2	3,564 (14.4)	18,570 (20.4)	
3	4,780 (19.3)	21,118 (23.2)	

Continued

Table 4 Patient and hospital characteristics for 90-day readmission analyses (*continued*)

Characteristics	Readmitted (n = 24,725)	Not readmitted (n = 90,946)	p Value
4+	14,934 (60.4)	40,010 (44)	
AIDS	171 (0.7)	400 (0.4)	0.0021
Alcohol abuse	3,507 (14.2)	10,755 (11.8)	<0.0001
Deficiency anemias	5,010 (20.3)	11,183 (12.3)	<0.0001
Rheumatoid arthritis/collagen vascular diseases	737 (3)	2,147 (2.4)	0.0027
Chronic blood loss anemia	71 (0.3)	246 (0.3)	0.7916
Congestive heart failure	2,375 (9.6)	4,737 (5.2)	<0.0001
Chronic pulmonary disease	5,017 (20.3)	13,321 (14.6)	<0.0001
Coagulopathy	1,591 (6.4)	3,773 (4.1)	<0.0001
Depression	4,426 (17.9)	14,729 (16.2)	<0.0001
Diabetes, uncomplicated	5,162 (20.9)	14,524 (16)	<0.0001
Diabetes, complicated	1,599 (6.5)	2,897 (3.2)	<0.0001
Drug abuse	2,886 (11.7)	10,784 (11.9)	0.6404
Hypertension	14,342 (58)	44,169 (48.6)	<0.0001
Hypothyroidism	3,348 (13.5)	9,945 (10.9)	<0.0001
Liver disease	1,194 (4.8)	2,508 (2.8)	<0.0001
Lymphoma	210 (0.8)	369 (0.4)	<0.0001
Fluid and electrolyte disorders	8,782 (35.5)	28,079 (30.9)	<0.0001
Metastatic cancer	768 (3.1)	1,474 (1.6)	<0.0001
Other neurologic disorders	57 (0.2)	155 (0.2)	0.2531
Obesity	2,135 (8.6)	6,764 (7.4)	0.0003
Paralysis	3,301 (13.3)	9,606 (10.6)	<0.0001
Peripheral vascular disorders	1,186 (4.8)	2,718 (3)	<0.0001
Psychoses	3,908 (15.8)	10,878 (12)	<0.0001
Pulmonary circulation disorders	568 (2.3)	974 (1.1)	<0.0001
Renal failure	3,807 (15.4)	6,759 (7.4)	<0.0001
Solid tumor without metastasis	703 (2.8)	1,942 (2.1)	0.0012
Peptic ulcer disease excluding bleeding	^a	13 (0)	0.2105
Valvular disease	1,068 (4.3)	2,963 (3.3)	<0.0001
Weight loss	1,253 (5.1)	2,848 (3.1)	<0.0001
Length of stay, d			<0.0001
1–2	9,488 (38.4)	47,479 (52.2)	
3–6	10,574 (42.8)	33,549 (36.9)	
7 or more	4,664 (18.9)	9,918 (10.9)	
Disposition			<0.0001
Home/routine	13,810 (55.9)	62,247 (68.4)	
Inpatient postacute care	6,330 (25.6)	15,665 (17.2)	
Home with home health care	3,612 (14.6)	9,564 (10.5)	

Continued

Table 4 Patient and hospital characteristics for 90-day readmission analyses (*continued*)

Characteristics	Readmitted (n = 24,725)	Not readmitted (n = 90,946)	p Value
Other	973 (3.9)	3,471 (3.8)	
Adverse events	2,248 (9.1)	6,502 (7.1)	<0.0001
Adverse events: medical care	507 (2.1)	1,078 (1.2)	<0.0001
Adverse events: drug care	1,799 (7.3)	5,556 (6.1)	0.0005

^a Data (n ≤ 10) not reported due to HCUP privacy guidelines.

Discussion

In this study, we describe a 30-day readmission rate of 10.8% in a nationally representative sample of hospital admissions. Prior studies have been in a variety of cohorts with differing primary outcomes (both seizure and epilepsy); they have additionally only examined subsets of the population such as members of a particular health plan or specific patient populations such as postsurgical patients.^{4–8}

The 30-day readmission metric is important as it is increasingly being used to assess hospital performance. Currently, the Medicare program (which is the payor for a substantial proportion of hospitalized persons with seizure in this national dataset) is no longer providing payment for inpatient care delivered within 30 days after an index admission for heart attack, heart failure, pneumonia, chronic obstructive pulmonary disease, elective hip or knee replacement, or coronary artery bypass graft surgery.¹¹ The list is likely to expand, and epilepsy would be a reasonable first neurologic disease to include, given its multiple treatment choices, and the clear association between outpatient epilepsy care quality and health outcomes across epilepsy subtypes.

Readmitted persons with seizure in our study had more medical comorbidities and were more likely to be discharged to another health care facility on their index admission than patients who were not readmitted. Of the comorbid conditions we could measure, several may predispose to seizure, provoke seizure in a susceptible individual, or be treated with a medication that can lower seizure threshold, including diabetes, metastatic cancer, renal failure, fluid and electrolyte disorders, and psychosis. Comorbid brain tumors, hemorrhagic stroke, and alcohol abuse were associated with readmission. This is consistent with the known increased risk of seizure in these chronic conditions.^{12,13} Subarachnoid hemorrhage and traumatic brain injury were interestingly not associated with readmission and this may reflect the static or slowly progressive nature of these diseases.

Participants with public insurance (Medicare or Medicaid) were associated with higher readmission rates as compared to participants with private insurance in this study. This may reflect unmeasured differences in comorbidity burden (for

example, one automatically qualifies for Medicaid with certain disability diagnoses); it may also reflect differences in post-discharge care resources, which may be more robustly provided by private insurers. In addition, the oldest age group (>85) was associated with a decreased likelihood of readmission; this may be due to increased (and unmeasurable) out of hospital mortality in this group, or may reflect an effort to avoid hospitalization in this group, perhaps as part of end of life care.

Remarkably, status epilepticus and altered mental status, diagnoses that one might predict would correlate with the severity of the seizure, were not significantly associated with readmission. Altered mental status and status epilepticus in our population may frequently be due to reversible, identifiable triggers in a sensitive population (persons with epilepsy). Although we used validated ICD-9 codes to identify adults with seizure, there is less certainty about the specificity of the ICD-9 code for status epilepticus, which could be used as a billing code for evaluation purposes (to justify long-term EEG monitoring or MRI). Patient safety and quality-driven hospital processes may support prompt or accurate identification (and treatment) of status epilepticus, subclinical status epilepticus, and altered mental status, thus reducing the potential for long-term injury. Future studies may better define which hospital structure and processes most strongly associate with favorable hospital outcomes.

Importantly, the most common reason for readmission was epilepsy/convulsion. This suggests that there is an opportunity for improvement as patients are not being readmitted for unforeseeable complications. Although documented adverse events were uncommon, readmitted patients were more likely to have had an adverse event during their index admission. The association with adverse medical events should be further investigated in a study with more granular, patient level data to better understand the health care structure (e.g., neurology intensive care unit, continuous EEG, neurology nursing) and processes (hospital protocols for neurologist consultations, long-term monitoring) associated with the presence (and absence) of adverse events. In addition, outpatient data are not available in this dataset, so one cannot examine the relationship between outpatient follow-up and readmission.

Table 5 Factors associated with 90-day readmission

Characteristic	Readmission rate, 90 days (row percent)	Adjusted odds ratio of 90 days readmission (95% CI)	p Value
Age, y			
18–24	1,301 (15.1)	Reference	
25–34	2,404 (17.3)	1.02 (0.9–1.15)	0.7491
35–44	2,788 (19.1)	1.04 (0.93–1.16)	0.5168
45–54	4,382 (21.8)	1.06 (0.94–1.19)	0.3345
55–64	4,968 (22.9)	1.01 (0.9–1.13)	0.8922
65–74	4,050 (24.2)	0.89 (0.79–1.01)	0.0781
75–84	3,004 (24.2)	0.82 (0.72–0.94)	0.0031
85+	1,827 (24.2)	0.8 (0.69–0.93)	0.0028
Sex			
Male	12,156 (21.1)	Reference	
Female	12,569 (21.6)	1 (0.95–1.05)	0.8741
Primary insurance			
Medicare	13,639 (25)	1.62 (1.49–1.76)	<0.0001
Medicaid	5,969 (22.6)	1.57 (1.45–1.7)	<0.0001
Private	3,144 (14.4)	Reference	
Self-pay/no charge/other	1,963 (15.3)	1.05 (0.95–1.17)	0.3360
Zip code quartile			
\$1–\$37,999	8,748 (22.6)	1.07 (0.99–1.15)	0.1105
\$38,000–\$47,999	6,343 (20.9)	1 (0.93–1.08)	0.9653
\$48,000–\$63,999	4,819 (20.4)	0.96 (0.89–1.05)	0.3897
\$64,000+	4,438 (20.8)	Reference	
Disposition			
Home/routine	13,810 (18.2)	Reference	
Inpatient post acute care	6,330 (28.8)	1.33 (1.25–1.42)	<0.0001
Home with home health care	3,612 (27.4)	1.3 (1.2–1.41)	<0.0001
Other	973 (21.9)	1.37 (1.22–1.55)	<0.0001
Elixhauser			
0–1	1,447 (11.4)	Reference	
2	3,564 (16.1)	1.4 (1.26–1.56)	<0.0001
3	4,780 (18.5)	1.55 (1.4–1.72)	<0.0001
4+	14,934 (27.2)	2.28 (2.06–2.51)	<0.0001
Length of index stay, d			
1–2	9,488 (16.7)	Reference	
3–6	10,574 (24)	1.33 (1.26–1.4)	<0.0001
7 or more	4,664 (32)	1.68 (1.56–1.81)	<0.0001

Continued

Table 5 Factors associated with 90-day readmission (*continued*)

Characteristic	Readmission rate, 90 days (row percent)	Adjusted odds ratio of 90 days readmission (95% CI)	p Value
Teaching status			
Metropolitan nonteaching	6,846 (21.4)	0.98 (0.93–1.04)	0.4957
Metropolitan teaching	16,371 (21.7)	Reference	
Nonmetropolitan	1,508 (18.4)	0.79 (0. –0.89)	<0.0001

Abbreviation: CI = confidence interval.

This study has limitations associated with administrative claims data, which contain codes produced for billing and documentation purposes. As discussed above, additional studies with richer clinical information, such as electronic medical records, will be helpful for understanding which health care structures and processes enable or prevent readmission. In addition, we are methodologically limited by the structure of the NRD, which does not allow us to track admission from one year to the next, and thus we were forced to censor some admissions due to inadequate follow-up. In

addition, we chose to use both validated epilepsy codes, although these have been validated in different administrative databases, not the NRD. We also used unvalidated convulsion codes, which are less specific for epilepsy but are more likely to reflect real-world conditions—capturing patients who would be admitted and cared for as though they had had a seizure. In addition, we used robustly validated codes for associated conditions and complications when available, but some diagnoses, such as those for substance use, have been less thoroughly studied. Finally, our data are from

Table 6 Comorbidities and complications associated with 90-day readmission

Characteristic	Readmission rate, 90 days (row percent)	Adjusted odds ratio of 90 days readmission (95% CI)	p Value
Associated conditions			
Brain tumor	892 (30.1)	1.42 (1.22–1.66)	<0.0001
Ischemic stroke	1,251 (23.6)	0.91 (0.81–1.01)	0.0817
Intracerebral hemorrhage	100 (35.1)	1.63 (1.1–2.4)	0.0142
Subarachnoid hemorrhage	14 (15.2)	0.53 (0.21–1.34)	0.1799
Traumatic brain injury	348 (19.6)	0.93 (0.77–1.14)	0.4957
Alcohol ingestion/dependence/intoxication/withdrawal	2,110 (26.8)	1.19 (1.09–1.29)	<0.0001
THC	0 (0.0)	NA	
Antidepressant nondependent abuse, poisoning by AEDs	18 (17.3)	0.83 (0.37–1.85)	0.6457
Sedative, hypnotics, anxiolytics intoxication/dependence	^a	1.03 (0.34–3.15)	0.9579
Cocaine, amphetamines, hallucinogens intoxication/dependence	0 (0)	NA	
CNS infection	196 (32.9)	1.34 (1.02–1.76)	0.0384
Associated complications			
Delirium/altered mental status	6,060 (25.2)	1.05 (0.99–1.12)	0.0953
Status epilepticus	2,707 (24.2)	0.98 (0.9–1.07)	0.7072
Mechanical ventilation/endotracheal intubation	2,226 (25.8)	0.95 (0.86–1.05)	0.3081
Shoulder dislocation	^a	0.43 (0.14–1.35)	0.1470
Aspiration pneumonia	1,022 (26.2)	0.92 (0.81–1.05)	0.2259

Abbreviations: AED = antiepileptic drug; CI = confidence interval; THC = tetrahydrocannabinol.

^a Data (n ≤ 10) not reported due to HCUP privacy guidelines.

Appendix 1 ICD-9 codes used for subcategories of patients and complications of seizure

Category	ICD-9 codes used
Brain tumor	191.x, 198.3, 192.0, 192.1, 192.8, 192.9, 239.6, 239.7, 237.1, 237.5, 237.6, 198.3 ^{14–16}
Ischemic stroke	433–437.1434.11, 436, 434.91 ^{17,18}
Intracerebral hemorrhage	431.x ¹⁹
Subarachnoid hemorrhage	430.x ¹⁹
Intoxication	Alcohol: 305.0, 303.x, 291.x, 790.3, 980.0, E860.0, E860.1 THC: 305.2, 304.3 Antidepressant abuse/poisoning by AEDs: 305.8, 966; Sedatives/hypnotics/anxiolytics intoxication/dependence: 305.4, 304.1 Cocaine, amphetamines, hallucinogens intoxication/dependence: 305.6, 305.3, 305.7, 304.1, 304.4, 304.5, 969.7, E854.2, 304.2, 968.5, E855.2 ^{20–22}
Traumatic brain injury	800, 801, 803, 804, 850.0–854.1, 959.01 ²³
CNS infection	006F, 013, 036A, 036B, 045–049, 052B, 053 A–053B, 054D, 054H, 055A, 056A, 062–064, 072B, 072C, 094, 136C, 320–325 ²⁴
Status epilepticus	345.2, 345.3 ¹⁰
Altered mental status/delirium	291.x, 293.x, 294.x, 310.x, 331.x/780.97 ²⁵
Mechanical ventilation/endotracheal intubation	96.7x, 96.0x ²⁶
Aspiration pneumonia	507.0 ²⁷
Shoulder dislocation	831.00

2014; future studies of secular trends in readmissions are needed to provide historical context and understand the extent to which outcomes can (or have) improve(d). In spite of these limitations, we present national data on short-term hospitalization outcomes of emergent admissions of adults for seizure in the United States. Further investigation into understanding preventable drivers of readmission in this population presents an opportunity to improve patient care.

Author contributions

L.J.B., D.P.T., J.A.G.C., and A.W.W. contributed to study concept and design. L.J.B., D.P.T., J.A.G.C., and A.W.W. contributed to data analysis. L.J.B., D.P.T., J.A.G.C., K.A.D., B.L., and A.W.W. contributed to data interpretation, writing the manuscript, and developing the tables/figures.

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Disclosure

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